The Smoke Nuisance; a Question of Conservation

By Raymond C. Benner and J. J. O'Connor, Jr.

[Reprinted from the Journal of Industrial and Engineering Chemistry, Vol. 5, No. 7, July, 1913.]

THE SMOKE NUISANCE; A QUESTION OF CONSERVATION[1]

By Raymond C. Benner and J. J. O'Connor, Jr.

Received March 13, 1913

INTRODUCTION

Neither for those who live in nor for those who even visit an industrial centre which burns a large quantity of bituminous coal, is a definition of the smoke nuisance necessary. Its effects are apparent on every side and no man, woman or child escapes them. The smoke nuisance is truly a modern plague.

It is only within the last few years that any serious study has been given to the various phases of the problem other than to the engineering. However, a remarkable change has taken place. There is not a city in the country that has the smoke nuisance in an acute form that is not aroused to the seriousness of the problem and is not attempting in one way or another to abate it.

It is rather appropriate that the city of Pittsburgh which, with its sobriquet "The Smoky City," has long been held up as the shining example of the smoke nuisance should be the center of an investigation which claims for itself comprehensiveness of plan if no other merit. It leaves no phase of the smoke problem untouched. The donor of the fund for this investigation was actuated by the belief that a thorough investigation would reveal not only the nature, extent, and precise cause of the smoke nuisance, but also the remedies that would make its abolition possible and practicable. To carry out this investigation, he placed $40,000 with Professor Robert Kennedy Duncan, Director of the Department of Industrial Research of the University of Pittsburgh.

In this paper we endeavor to present the various phases of the problem as they have come to our notice in our work in the smoke investigation.

THE CHEMISTRY OF SOOT

When one considers the very different conditions under which coal is burnt, it is obvious that the character of soot must vary. All conditions in the furnace greatly affect the amount of carbon lost in soot, but the fact stands out that where equal amounts of coal are consumed domestic installations are worse offenders than boiler furnaces. Loss of efficiency through the escape of soot itself is small. This is, however, an indication of a far greater loss in the shape of unburned, invisible gases, which loss may be as high as 10 per cent.

Soot consists of:

(1) Carbon in a finely divided state. This, as is well known, is lamp-black, the basis of most black paints and has a great

[1] An address delivered at a recent meeting of the Canadian Conservation Commission.

covering power. It has the power of absorbing the corrosive acids which are produced by the combustion of coal containing sulfur.

(2) Tar. It is common coal tar which makes the soot cling tenaciously to everything with which it comes in contact. Tar contains carbolic acid and a large number of other compounds of an injurious nature.

(3) Acids. Sulfurous acid; sulfuric acid; hydrogen sulfide; hydrochloric acid together with a number of organic acids.

These acids corrode and tarnish all of the common metals. They attack many of the stones and building materials, especially limestones. Draperies, paper, paints and other decorative materials suffer to no less extent. In burning the sulfur in the coal, the relatively inactive sulfurous acid is for the greater part produced, but this soon becomes oxidized in the air to the far more active and corrosive sulfuric acid. These acids are also poisonous and detrimental to health.

Fig. I—A Pittsburgh Building Partially Cleaned

(4) Ash. This is the least injurious of all the constituents of smoke and may be, for all practical purposes, considered as common dirt.

(5) Ammonia is found in soot only in very small quantities and is of less importance than the other corroding agents.

(6) Arsenic. This poisonous substance has been found in small quantities (generally less than 0.1 per cent. of the soot).

The amounts of these constituents of black smoke vary between the widest possible limits, depending upon the composition of the coal, methods of firing, amount of air, temperature of the furnace, etc. The following analysis of soot taken from Cohen and Ruston's "Smoke, a Study of Town Air" gives a good general idea of what one must expect.

Dr. Russell found that the rain water did not contain acid unless it also contained soot. The amount of free acid in nine samples calculated as sulfuric acid was found to be: 1.4 per cent.,

Smoke prevention

CALL SLIP FOR RESERVED BOOKS

Call number	AUTHOR
920.042 H58 cop 2	
	TITLE

Reserved books are to be consulted in the Reading rooms only. The signer of the call slip must return the book to the Loan desk before leaving the room.

Reserved books may not be loaned from the library except when the Reading rooms are closed; and when so loaned they must be returned by the time the library next opens; failure to do so subjects the borrower to a fine of twenty-five cents a day.

Signature of borrower Helen Stevens

UNIVERSITY OF ILLINOIS LIBRARY

0.5 per cent., 7.2 per cent., 0.0 per cent., 4.9 per cent., 0.8 per cent., 1.2 per cent., 2.3 per cent., 0.0 per cent.

INDUSTRIAL SOOT—SOOT FROM BOILER FURNACE

	Original coal	Boiler chimney			
		Bottom	13 feet from base	70 feet from base	Top of 110 ft. chimney
Carbon	69.30	19.24	16.66	21.89	27.00
Hydrogen	4.89	2.71	0.86	1.44	1.68
Tar	1.64	0.09	0.28	0.80	1.14
Ash	8.48	73.37	75.04	66.01	61.80

DOMESTIC SOOT

Constituents	Coal	Kitchen flue	Dining room flue	
			Bottom 5 ft. from grate	Top 35 ft. from grate
Carbon	76.80	52.34	36.45	37.22
Hydrogen	4.90	3.68	3.51	3.51
Tar	0.88	12.46	34.87	10.38
Ash	1.80	17.80	5.09	4.94

THE PER CENT OF FREE ACID IN SOOT

Sources of sample	Base of chimney	Top of chimney
Brass foundry	0.00	0.65
Study flue	0.50	....
Kitchen flue	0.0	....
Boiler chimney	1.62	0.56
Fireplace	0.37	0.00

From the above analyses it is seen that the amount of tar and carbon in the soot from domestic fires is much higher than that from boiler furnaces, while in the case of ash the reverse is true. Domestic soot is thus by far the more objectionable and is produced in greater quantities from the same amount of coal. The amount of acid depends more upon the amount of sulfur in the coal than upon any one factor and is given off with the products of combustion whether smoke is produced or not. When, however, soot is produced, a large percentage of the acid is occluded in the soot, where it is more injurious than if allowed to escape alone into the air. The soot coming in contact with metal, stone, decorations, etc., is made to adhere firmly by means of its tar content, in reality covering the surface with a coat of black paint. The acid is not readily washed away by the rain, but continues to act until it is all used up. This acid absorbed from the air by the rain water would be more injurious if it did not drain off from most surfaces before its action was completed.

DETERIORATION OF BUILDINGS AND BUILDING MATERIALS

After considering the various phases of the chemical composition one can readily understand why houses in a smoky atmosphere look grimy and miserable and why the use of skylights is in many places made impossible, while in others it is necessary to so arrange them that they may be readily cleaned Otherwise they would soon become unsightly because of the accumulation of soot. Again, changes in design to make a different arrangement of drain pipes, etc., are, at times, necessary in order to prevent the splashing of rain water containing soot upon the building.

In a smoky city, too, much more glazed tile and vitrified brick are used for the outside of buildings, as it makes the cleaning a comparatively simple matter, washing alone being necessary. Building stones, such as limestone, marbles or sandstones with calcareous binding material are rapidly disintegrated by the acid in the soot and air. Therefore materials such as granite, sandstone (with a siliceous binding), brick, etc., which are not readily attacked by the sulfurous and sulfuric acids in the soot, should be utilized. But unfortunately, that stone which is most easily affected, disintegrated by the atmospheric acid and decolorized by soot, is the one which it is easiest to work into the desired shape for building purposes. Granite and similar stones which are practically unattacked by acid and impervious to moisture, and which are readily cleaned, are extremely expensive because of the difficulty in working. Thus the architect finds himself confronted with monetary as well as esthetic considerations. Stone may be cleaned but to say the least, it is but a temporary expedient and represents a periodical tax on the owner. The logical thing is to make cleaning unnecessary by water-proofing the stone and doing away with the smoke. The sulfuric acid acts on the calcium carbonate (the principal constituent of stones most easily corroded by the acid in the soot), forming calcium sulfate (gypsum) which is more soluble in water than the calcium carbonate but, at the same time, causes the stone to undergo a physical change, making it swell and become porous and friable and easily disintegrated, also roughening polished surfaces, thus making them more readily attacked by acid and moisture and affected by weather. Dr. Angus Smith has found mortar to contain as high as 28.33 per cent. of sulfuric acid, equivalent to 48.16 per cent. $CaSO_4$ caused by the action of the sulfuric acid in the air on the calcium carbonate.

The effect of the sulfuric acid on most metals is rather marked and greater than the action of a like amount of acid in the rain water or air. It would seem from observations taken in Pittsburgh, that where soot containing acid is made to adhere to the metal by means of its tar content, an electrolytic action is set up, making corrosion much more rapid. In case of iron and aluminum, the oxide and basic sulfate are produced, at least in part, from the sulfate, and the acid is used over and over again. To experimentally verify these observations, duplicate sets of various metals were fastened to two boards. One set was protected from the soot in the air by means of cheese-cloth, yet still exposed to the air and rain. The other set was left unprotected. The pieces of metal left unprotected from the soot show a greater amount of corrosion than those which were protected. I wish, here, to call your attention to the following figures obtained by Messrs. W. B. Worthington and A. Rattray, showing the corrosive effect of the acids in the air. Quoting from Cohen, "A number of rails were placed in suitable positions by the side of the line, and weighed at intervals and the loss in weight recorded. The rails were of the ordinary railway section

weighing 86 lbs. per yard. The annual loss of weight from corrosion was as follows:"

	Loss in wt. in lbs. per yd. per average year	No. of years of observations
1. In the center of the town	1.04	17
2. In dry place in smoky tunnel	1.48	13
3. In a wet place in same tunnel	1.71	8
4. On the seacoast among sand hills	0.18	17

The question of exterior and interior decoration is one affected as much by the amount of smoke in the air as by the tastes of the owners of the buildings.

Interior draperies and paper are soiled much quicker in a smoky city than elsewhere. If light paper is used in papering the rooms, it must be cleaned every six months and new paper put on every year to keep it looking only half as well as one would wish.

The acid in the soot attacks draperies, rendering them useless in a short time. The extra wear of cleaning shortens the life markedly. On interior painting the effect is not as marked because cleaning is done about every so often anyway. But the problem of interior decoration and keeping the outside of a building clean are problems, indeed, and next to an impossibility in some smoky places. The statement has been made to us by a number of painters that they have done jobs which looked really as bad after two or three days as they did before they were painted. Soot certainly destroys the esthetic value of paint very quickly. The time it takes to accomplish the pollution is, of course, dependent upon the amount of soot in the air, the color of the paint, tar in the soot, etc. The number of paintings necessitated to keep the same building as presentable as in a smoke-free city will naturally vary greatly. Cases can be cited where it is necessary to paint three or four times as often as would be required for protection. In the majority of cases in smoky cities the number of paintings required is probably doubled. Sometimes it is necessary to remove the soot and tar and to wash the building before applying the next coat of paint. This washing also removes the paint, often making necessary two coats in place of one for a proper covering. After the wood has received ten to twelve coats it is customary to burn off the paint. This is an additional expense and likewise endangers the house with fire. The action of soot on the wearing qualities of the paint also depends on many factors involving the chemical composition of the paint and soot. The soot may be acid, neutral or even slightly alkaline. Places are known where the soot is thought by some to act as a protective coating, while in others it is corrosive to the painted surface, destroying the gloss and rendering it much more easily weathered. The latter is probably true in those cases where the coal burned contains a lot of sulfur and the soot is consequently quite acid.

SMOKE AND THE WEATHER

From a preliminary study of available data and a perusal

of the literature concerning the meteorological branch of our work, Dr. H. H. Kimball arrived at the conclusions:

(1) That city fogs are more persistent than country fogs, principally because of the increased density due to the smoke which accumulates in them.

(2) In consequence of the fog prevalence there are fewer hours of sunshine in the city than in the country.

(3) The sunshine is less intense than in the surrounding country, the light of short wave length of blue light suffering the greater depletion.

(4) Daylight, which often depends entirely upon diffuse daylight from the sky, is depleted by smoke in greater proportion than direct sunlight.

(5) Minimum temperatures are markedly higher in cities than in the country, in part, of course, because of city heating, but principally because the smoke acts as a blanket to prevent the escape of heat at night.

We find when using a chemical method for determining the intensity of daylight that on some days there is two or three times the light as measured by chemical action, ten miles from the center of Pittsburgh as there is in the city proper.

The amount of soot in the air varies greatly, depending upon the direction and strength of the wind, etc. We have found variations between 0.0015 to nearly 0.2000 gram per 1000 cu. ft. We have many more times the soot in the air on some dark days that we have on clear, bright days.

Visibility determinations (the distance one can see) vary greatly from day to day. With the accumulation of more data we hope to trace a relationship between these determinations and the amount of soot in the air.

The soot-fall (the amount of soot which falls on a given area in a given period of time) is of interest to us from many viewpoints. A large number of determinations have been made, and although they vary greatly in different parts of the city, those made at the same stations remain remarkably constant. The total fall varies between 720 and 2280 tons per square mile per year for the cleanest and dirtiest parts of the city, respectively. These figures represent the entire dust-fall, which is jet-black and is considered here, as elsewhere, to represent the soot-fall. Analyses are, however, being made for tar, organic and inorganic matter.

HOW VEGETATION IS AFFECTED BY SOOT

Trees, shrubs, etc., are utilized in a city as adjuncts of beauty, rather than a source of income, and as the smoke nuisance, as a rule, is prevalent only in cities of some size, its effect is not felt on the crops in the country district. Therefore, the effect of soot on vegetation would be considered more particularly a question of esthetics. Yet it makes felt its injurious action, both directly and indirectly. The smoke clouds limit the available daylight in two ways:

The amount of sunlight as well as diffuse daylight is not nearly as great in a smoky city as it normally should be.

If the amount of light cut off by the deposit of tar upon glass can be considered in any sense as a measure, the tar deposit on the leaf is by far the most important factor in light absorption.

The tarry matter contained in the soot coats the leaves and chokes the stomata. This injury is mechanical. Its destructive action does not, unfortunately, stop there. Like all other forms of finely divided carbon, soot has the power of occluding other substances. The tar, acids, etc., are all poisonous to plant growth and greatly lower the vitality, the acids in particular limiting the activity of the soil organisms, especially those of nitrification.

Cohen and Ruston find that the relative assimilations of laurel leaves in districts where the air contains different amounts of soot, etc., vary from 11.6 to 100. Crops of radishes and lettuce grown in different sections of the town show the possibility of correlation of the known atmospheric impurities with the yield of the crops. Trees automatically keep record of the presence of any inhibiting factor by the narrowing of their annual rings. In one case the cross section of a tree plainly showed evidence of the building of a smoke-producing factory near at hand.

We find that such flowers as roses, carnations, etc., will not thrive within the city limits of Pittsburgh, and that for this reason many greenhouses have been forced to move beyond this deleterious influence. Furthermore, many of our trees are injured if not entirely killed by the smoke.

SMOKE AND DISEASE

The effect of smoke on health has always been a much mooted question. At the present time in the city of Pittsburgh it has assumed a very practical form. The city has appropriated considerable money for a tuberculosis hospital and a dispute has arisen as to its location. Some contend that it should be placed outside the city limits, while others hold that more intensive work can be done if it is located in that part of the city where the disease is most prevalent. The advocates of the first location, as part of their argument, assert that the smoky atmosphere is detrimental to those suffering from the disease or at least that it retards their recovery. The weight of opinion seems to be against this view.

Dr. William Charles White, in a paper read before the Fifteenth Congress of Hygiene and Demography said: "As a result of our clinical study we have come to the conclusion that the general death-rate from tuberculosis in Pittsburgh is low, that there is nothing in the smoke content of the air which in any way stimulates the onset of tubercular process or militates against the rapidity of recovery from tuberculosis when once this disease has been contracted."

Dr. White's studies along this line, however, led him to declare that from his study of the air content of Pittsburgh and of disease that smoke has an important bearing on the pneumonia death-rate, in fact that it is nearly proportional to the soot-fall.

Dr. White is in favor of a popular crusade for the prevention of pneumonia like that which has been waged against tuberculosis. Of course, in such a campaign serious attention would be given to the smoke problem.

Dr. Louis Ascher, of Königsberg, who has made an extensive study of the effect of smoke and dust on disease maintains that in Germany a smoky atmosphere is responsible for the increased mortality from lung diseases other than tuberculosis. He holds that not only is this increase taking place, but that persons who are the subjects of pulmonary tuberculosis die in smoke-

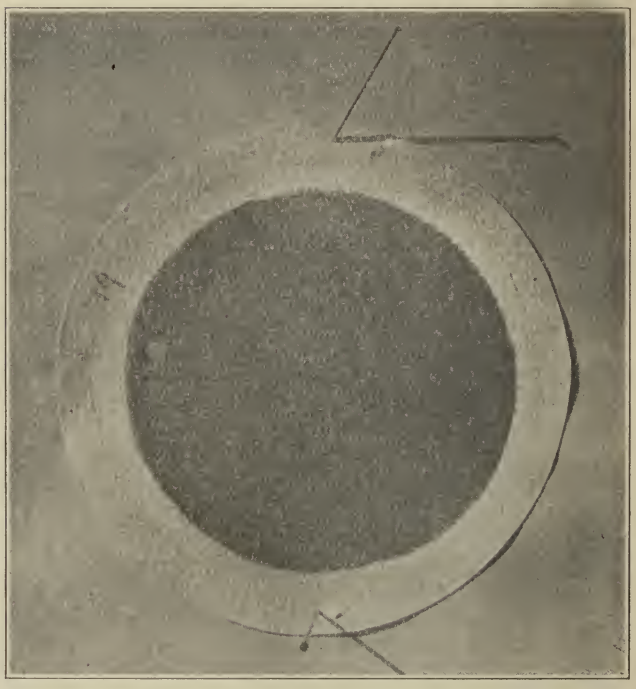

Fig. II—Filter Paper through which the Amount of Air Breathed by a Man in One Day Has Been Filtered

laden districts more rapidly than those persons similarly affected, but living elsewhere.

Of the fact that carbon makes its way into the lungs of those who live in a smoky city, there is no doubt. Dr. Oskar Klotz finds large amounts of it in the lungs of Pittsburghers; 10.6 grams were found in the lungs of a street peddler 28 years of age.

According to Lehmann, while the sulfur dioxide contained in the soot is absorbed by the nasal mucous membrane, the particles of carbon are carried further into the respiratory passages. Finally reaching the lungs, they are deposited there having meanwhile in their descent given up to the bronchial mucous membrane and the lining membrane of the lungs some of the acids they retained.

Dr. W. L. Holman finds that soot acts as a disinfectant, the

moist being more active than the dry. (Water seems to dissolve the disinfecting agents in the soot, making them more active.) Carbon floating in the air seldom if ever carries bacteria unless it has lodged on the ground and is again blown into the air. Soot acts as a very effective blanket, protecting the bacteria and giving them a chance to grow.

Dr. E. W. Day finds that diseases of the nose and throat are not appreciably more prevalent in smoky cities, but that they are more severe and harder to cure. This is probably due as much to the cracking of the mucous membrane by the dry atmosphere in the houses and subsequent irritation by dust as by the smoke. Singers, on visiting Pittsburgh, usually get Pittsburgh sore throat, which lasts about seven days, when they become acclimated for the time being. Unfortunately though, the same thing occurs on each succeeding visit to the city.

THE COST OF SMOKE

We are coming more and more to look at the smoke problem as fundamentally an economic problem. We have been told time and time again that smoke and soot are the products of imperfect combustion which means a waste of fuel, and a waste of fuel means an unnecessary expense. But there is more than this to the question; smoke is not only a cause of expense to the maker of it, but it is a cause of expense to every man, woman and child in the community.

Various estimates of varying degrees of accuracy have been made of the financial damage due to smoke and soot. In 1905 the Hon. F. A. Rollo Russell estimated the damage in London to be $26,000,000. The largest single item of this amount was $10,750,000 for extra washing and wear and tear of linens. The Cleveland Chamber of Commerce in 1909 placed the per capita loss for that city at $12.00 or $6,000,000 for the entire population. Mathew Nelson, Chief Smoke Inspector of Cincinnati, asserted that the loss there was $100.00 per family. Mr. Paul Bird, in his report as Chief Smoke Inspector of Chicago, declared that the loss in Chicago was at least $17,600,000 or $8.00 per capita. In a paper read before the American Civic Association, Herbert M. Wilson, Chief Engineer of the United States Bureau of Mines, stated that a careful government inquiry into the toll paid by the people of the United States showed a total of over $500,000,000 or a per capita toll of $17.00 a year for every man, woman and child in the larger cities.

These figures startle. It is the task of those who are engaged in the economic phase of the smoke investigation to make estimates for Pittsburgh as accurate as possible by inquiring into the various items that go to make up the total. They are attempting to deal not in sweeping generalizations, but in what Mr. Wood, in speaking of the work of the Pittsburgh Survey, termed, "Piled-up actualities."

About 25 per cent. of the cleaning expense of office buildings in the city of Pittsburgh is due to smoke. When you realize that the cleaning bill of some of our office buildings is $75,000

per year, you know well what a toll is placed on them. To cite a single item—it costs a certain building in Pittsburgh $320.00 more a month for window cleaning than if the building were located in New York or Philadelphia. The lighting bills in office buildings are increased by half because of the conditions of the atmosphere in Pittsburgh.

The damage to goods in wholesale, retail and department stores runs up into the thousands, amounting to as much as $30,000 a year in the case of one store. We have found that it costs from 33 per cent. to 50 per cent. more to conduct a hospital in Pittsburgh than in other cities. For instance, in the matter of extra cleaning force, one hospital could save $3,000 a year, and another $1,200 if the city were cleaner. You have noticed, no doubt, the number of buildings in large industrial cities that are washed down or painted once or twice a year. To one firm in Pittsburgh this means an extra expenditure of $700.00 and in the case of another firm, of $500.00.

Census reports on laundries show that Pittsburgh pays more than most comparable cities and that it costs the laundrymen more to do the work. These figures when compared with the report of smoky days in various cities seem to indicate that atmospheric conditions and not custom determines, in a large measure, the per capita amount of business done.

The schedules of men who now live in Pittsburgh but who come from other cities show that they pay from one-third to a half more in Pittsburgh. They wear at least two more shirts and two more collars per week which means an extra expense, at the lowest, of $16.00 each year. Schedules of women who have lived in other cities show that they pay $24.00 each more a year in Pittsburgh than elsewhere. The toll paid to steam laundries alone amounts to something like $800,000. The extra expense in labor, time and effort in home laundry work is much greater than that of steam laundries. As a minimum estimate Pittsburgh pays a toll of $1,500,000 in laundry and home washing bills.

Dry cleaning is found necessary far more frequently in Pittsburgh than in other cities because of the atmospheric conditions. Because of this a greater supply of clothing is required and clothes wear out sooner. Moreover, Pittsburghers are limited in the selection of colors of clothing. Especially is this true of woolen goods, furs, hats, trimmings, etc. The average annual bill of a man in Pittsburgh who sends his clothes to a dry cleaner is $18.00; a woman's bill is about $20.00. This is half more than the man or woman would pay in a cleaner city. The total extra cost of dry cleaning in the city of Pittsburgh is about $750,000.

In October, 1912, the Philadelphia assessors, in answer to the appeal of the property owners in the 24th and 44th wards of that city, who declared that recent sales in their vicinity were at prices far below the assessed valuation because of the smoke nuisance, reduced the assessed valuation of each from $500 to $2,000 on some three hundred properties. A preliminary survey of conditions in Pittsburgh showed that the same

facts were here true. In some sections there has been a depreciation of fully 50 per cent. in sale price. Such property is near mills or railroads or, as is often the case, near both. Houses in such neighborhoods are very difficult to rent and in order to rent at all, there must be a reduction in the rental price of at least 20 per cent. Sometimes people rent these houses and move as soon as they become acquainted with the nuisance.

To all these losses—and there are many others—must be added the cost of the fuel wasted through imperfect combustion. In 1881, when a little less than 3,000,000 tons of coal were being used in Pittsburgh, William Metcalf, an eminent engineer and mill owner, estimated the cost of the coal that was sent, wasted, out of the tops of the stacks at $1,063,000. At the present time Pittsburgh burns in the neighborhood of 15,000,000 tons of coal annually, the cost of which is about $19,000,000. It has been estimated, on the basis of efficiency tests, that there is a loss of $4,000,000 annually which could be saved by proper furnace operation.

FACTORS TO BE CONSIDERED IN THE ABATEMENT OF SMOKE

As a problem the smoke nuisance presents many and various phases. In the method of attack in the different cities there are a number of factors which must be taken into consideration.

1. The topography of the country is an important factor in the mitigation of the evil. A hilly country, such as we have in Pittsburgh, confines the smoke to the valleys, so that it is not readily carried away by the wind as it is in Chicago and other cities built on a flat country.

2. The location of the smoke-producing plants with reference to the residence district must be taken into consideration. In many places this proves a source of great annoyance, in others tends to simplify the problem. In Pittsburgh the mills are situated along the Ohio, Allegheny and Monongahela rivers, which run through the city, bounding at least three sides of our best residence districts. Recalling the topography of the city you can see that this does not facilitate abatement.

3. The necessity for burning soft coal in private dwellings is a great bane, the methods for burning it without smoke not being nearly as well perfected as in case of large installations. About 6 per cent of the coal burned in fireplaces and other domestic installations escapes through the chimney as soot, while only about 0.5 per cent of that burned in power plants is thus wasted; that is, weight for weight, the coal burned in domestic installations is twelve times more a nuisance than that burned in a hotter furnace under a boiler. Cities which have at their disposal a supply of natural or other cheap gas are greatly favored.

4. Cities, such as Philadelphia, which have access to cheap hard coal, should have very little need of consideration in connection with our problem. Anthracite coal is a smokeless coal. In fact, soft coals vary greatly in the ease with which they are burned without smoke. Different types of mechanical stokers

and other kinds of installations are required in many cases. Each district presents new engineering problems. An installation which gives perfect satisfaction with one kind of fuel will not of necessity do so with another.

5. Smoke abatement is not a difficult task in non-manufacturing towns where power plants are the exception rather than the rule. In manufacturing towns, on the other hand, long-continued campaigns of education are necessary before even the enforcement of an ordinance is possible.

Fig. III—A Low Stack among High Office Buildings

After a thorough perusal of smoke literature and a general survey of the smoke-producing plants in this district, a number of facts were firmly imbedded in our minds:

(1) That the production of smoke was in most cases unnecessary and could be prevented with economy to the power plant operator.

(2) No thoroughly practical method is known for abating

the smoke in roundhouses, coke ovens, brick kilns and one or two special furnaces.

(3) However perfect a smoke preventing device has been installed, it will not be of much value for the prevention of smoke unless intelligently operated, *i. e.*, the fireman must be educated to do his work in a proper manner.

(4) The public in general were of the opinion that in order to be prosperous the city had to have smoke, *i. e.*, that it meant industry and prosperity.

(5) No investigation of the subject as a whole had been made by the coördinated efforts of a group of men.

We find that certain types of installation are notorious smokers while others are practically free from smoke at all times.

Furnace Type	No. of stacks observed	No. violating the city ordinance
1	45	26
2	21	3
3	8	0
4	23	15
5	15	0
6	1	0

The human element must not, however, be neglected in this connection. It is possible for a skilled fireman to operate a hand-fired furnace without objectionable smoke even if it is not constructed in the most approved manner. But given an unskilled or careless man in charge, the most modern of plants may become an objectionable smoker.

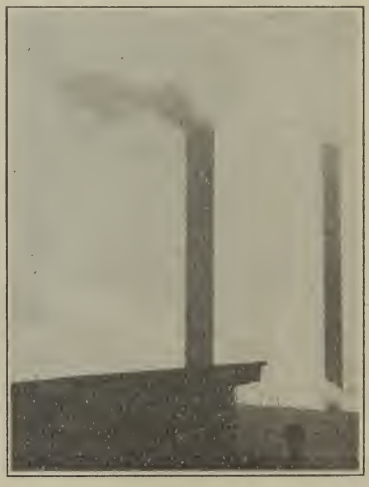

Fig. IV—Hand-Fired and Stoker-Fired Stacks

To do away with smoke and increase efficiency one must bear in mind three things:

1. The mechanical contrivance for burning the coal must be suited to the purpose.

2. The fireman must be trained to do his work in a proper manner.

3. Some method of furnace control should be employed (CO_2 recorders, pyrometers, etc.) so that the efficiency of the furnace, amount of smoke, etc., may be known both to the fireman and superintendent.

THE QUESTION OF LEGAL REGULATION

As legislation follows rather slowly the agitation for and need of certain reform measures and as the question of smoke abatement in the United States is of comparatively recent date,

we need not be surprised to find that the passage of ordinances on the subject, especially of ordinances that are in any way effective, has taken place in only the last ten years. This is not true, however, of England where the law took cognizance of the smoke nuisance as early as 1273, when the use of coal was prohibited in London as prejudicial to public health. There is in existence a statement that one John Doe was, in 1306, tried, condemned and executed for burning coal in the city of London. Since 1273 there have been numberless proclamations, parliamentary commissions, laws and ordinances on the smoke nuisance.

It was about thirty years ago that cities of the United States began to pass smoke ordinances. However, as early as 1856 an ordinance was introduced in the council of Cleveland to prohibit the use of soft coal in manufacturing plants, and some time prior to 1869 Pittsburgh passed an ordinance which contained the provision "that no bituminous coal or wood should be used in the engine or any locomotive employed in conducting trains upon any railroad." Chicago and Cincinnati were the first cities to pass general ordinances on the subject, the first ordinance in Chicago being passed in 1881. Pittsburgh did not have an ordinance until 1891 and then it was for only a section of the city.

At the present time all of the cities having over 200,000 population, with a few exceptions—and in these cities the problem is not acute—have smoke ordinances, as have many of the smaller cities which are far-sighted enough to be on their guard, lest this modern industrial plague come upon them in its full wrath.

The source of power of governmental authority to abate the smoke nuisance is the police power of the state. We are always tempted to think of this as extending only to the protection of life and property in its narrow sense and the maintenance of public order, but more and more we are coming to know that its great sphere is public health and general welfare. This police power may be delegated by the state legislature to municipal corporations, and this is the power under which municipalities declare certain acts nuisances. While a municipality may be authorized in general terms to declare what shall constitute a nuisance, it may not declare that to be a nuisance which in fact is not. In common law "dense" smoke was not a nuisance *per se* though some courts have held it to be so in a populous city.

The Pittsburgh ordinance of 1906 was held void for two reasons, one of which was "that the Legislature of Pennsylvania had likely not given the city sufficient authority to pass an ordinance upon the subject." The city at once sought and secured the power. Thus it can be seen that in order to deal with the smoke nuisance, cities should seek specific authority from the legislature.

When a municipality is thus empowered it is then in position to pass an ordinance. It is a difficult matter to say what the essential provisions of a smoke ordinance should be and yet

from the experience of the different cities we are able to select certain features that are necessary if the ordinance is to accomplish any notable results.

In our day and generation we are looking to preventative rather than remedial legislation for telling achievement. This thought leads us to one of the fundamental functions of a smoke ordinance: that it should make provision for prevention as far as possible of the installation of improperly designed furnace equipment. For this purpose the ordinance should provide that plans and specifications for all construction work on furnaces be submitted to the smoke inspector and approved by him before the work is started.

Fig. V—A Steel Mill—One of the Worst Offenders

This feature leads us to the point that since it is so important a provision, the ordinance should state the qualifications of the man whose duty it is to pass on these plans and specifications. Surely it should provide that he be an engineer, "qualified by technical training and experience in the theory and practice of the construction and operation of steam boilers and furnaces."

An ordinance, of course, should state the density of smoke that is to be permitted and provide a standard of measurement. On the first point, care should be taken lest the provision be somewhat vague, for this has been the rock upon which many ordinances have been wrecked in courts. In speaking of this feature—the fixing of the density—Mr. S. B. Flagg, of the

United States Bureau of Mines, says: "The requirements should represent the best practice, the standard set should not be an impossible nor an impracticable one, neither should it represent ordinary or poor practice. In some ordinances a stack well within the limits as set by the ordinance may be responsible for the discharge into the atmosphere of many times as much soot as another stack which violates the ordinance.

The mere enactment of a reasonable, efficient and enforceable smoke ordinance is not enough. The ordinance must be enforced. At this point most of the cities have fallen short. Sometimes the wrong methods are used in the enforcement of the ordinance. Most of the time the methods employed are altogether too lax and feeble to secure even mediocre results. To remedy this situation there is one great weapon—public opinion. However, in order to educate, concentrate and focus public opinion, a league or union of civic and commercial organizations should be formed in each city. Such organizations seem imperative in American cities until better results are secured by way of enforcing smoke ordinances. Eternal vigilance on the part of the public is the price of a smokeless atmosphere, but to those who enjoy such a blessing the price is not a whit too high.

Enough has been said to suggest that the smoke nuisance is an economic question and that the people who are most concerned are not those who make the smoke but those who suffer because it is made. It is necessary, therefore, to educate the public as to the evils of the nuisance, that an active and intelligent public opinion may be brought to bear on those who are responsible for it. As has been pointed out, even with the smoke makers this problem is an economic one. The abolition of the smoke nuisance, therefore, unlike many other social nuisance against which outcry has been made, would result in direct and immediate gain both to the public-at-large and to those who are chiefly responsible for the nuisance itself.

Department of Industrial Research
University of Pittsburgh